LUBRICATION

A Technical Publication Devoted to the Selection and Use of Lubricants

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The Marine Steam Turbine

THE marine steam turbine became an ideal toward the latter part of the nineteenth century when Parsons and De Laval, around 1885, were developing their principles of blade design and perfecting their ideas for the generation of power in stationary service. It was not until several years later, however, that ways and means to step-down turbine speeds to propeller shaft speeds were made practicable in the form of the herringbone or double helical reduction gear.

The geared turbine has proved its adaptability most conclusively and indicated definite economic and maintenance advantages. Credit for its development should in turn be given to De Laval, Westinghouse, Melville and Macalpine. When these latter two investigators demonstrated the thrust-absorbing characteristics of the double helical gear design and proved the practicability of designing for large speed reduction ratios, the marine steam turbine became an actuality.

At about the same time research in air pump and condenser design enabled an approach to a state of almost perfect vacuum at the exhaust; which led to a marked improvement in operating efficiency, heat transfer and steam economy by enabling more complete expansion of the steam.

Electric Drives

In contrast to the method of ship propulsion by means of speed reduction gears, later developments have incorporated electric generators driven directly by the turbines. The United States Navy can be credited with the foresight of anticipating the advantages to be gained from this method of drive; their investigations dating back to 1908. In this design current from the generators is applied through slow-speed motors to drive the propellers. Electric drive has proved to be highly flexible, speed changes can be rapidly made and reversing is simplified.

The Petroleum Chemist Cooperates

Concurrent with the efforts of mechanical engineers to perfect a practicable turbine for marine service, chemists of the petroleum industry were studying the characteristics of the derivatives from the crude oils available at the time, to produce turbine oils of maximum stability and resistance to sludging. These requirements have never changed; the investigators of a generation ago presumed that turbine bearings and gear elements required positive and continuous lubrication; their more recent followers proved the wisdom of their presumptions.

So the refining of turbine oils has become one of the major problems of the petroleum industry. As steam pressures increased, the requirements were intensified, for bearing temperatures were often higher, oils were subjected to greater loads and oxidizing conditions were often acute. This led to solvent extraction and other methods of refinement which the chemist proved were beneficial in removing unstable compounds, and the development of lubricating oils of high resistance to oxidation and emulsification.

LUBRICATING SERVICE CONDITIONS

Marine machinery must be designed with a degree of rigidity and strength entirely uncalled

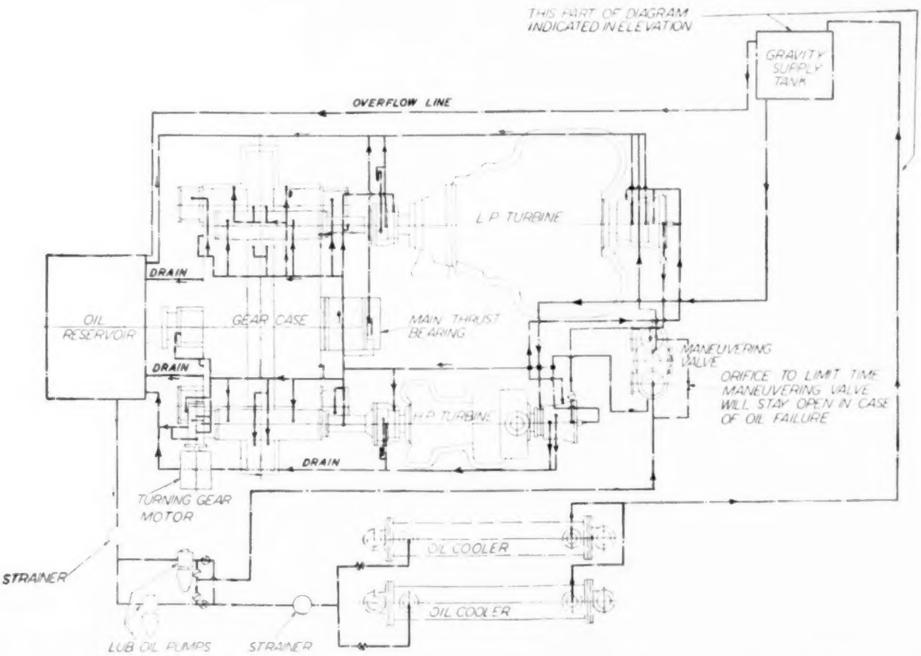
for in land practice in order to withstand prevailing variations in stress and strain. The laboring of a ship in a sea-way, the variable propeller load and differences in cargo loading, all contribute toward making even the lightest duty relatively difficult under such varying conditions. The tunnel bearings of the propeller line shafting of a vessel are a good illustration of this, as the temperature of these bearings is constantly changing as the loading or weather conditions vary. A bearing running cold one day may be hot and require constant attention the following day if loading and weather conditions change materially. Vibrations while underway are always more or less a source of difficulty and are present in every part of a ship's structure, especially with high-powered, fast running vessels.

The marine engineer who is charged with the operating and lubrication of turbine propulsion machinery on shipboard normally has but little to say in regard to any alteration or improvement in design. It is required of him to keep his machinery in condition, ready for instant orders from the bridge. In maintaining his lubricating equipment, he must recognize certain factors which may materially affect the dependability of his turbine, viz.:

(a) The possibility of water contamination.
(b) The probability of the oil being overheated.
(c) The occurrence of oxidation, and
(d) The ultimate formation of organic acids and sludges.

CHARACTERISTICS OF MARINE TURBINE OIL

To most effectively withstand these breakdown conditions, a marine turbine oil should be a highly-refined, pure mineral oil; it should separate readily from water with which it may come in contact, that is, it should not form permanent emulsions with water. Furthermore, it should be of such viscosity as to function most satisfactorily on the particular type of turbine being lubricated.



Courtesy of Westinghouse Electric & Mfg. Company

Fig. 1—Plan of a typical oiling system as designed by Westinghouse for Marine Turbine Service. Flow of oil from the supply tank (shown in elevation) to the bearings and gears and thence to the return tank can be clearly followed.

Carefully refined turbine oils are so processed that they are practically free from easily oxidizable compounds, dirt or any other mechanical impurities. This high degree of purification is accomplished by filtering the oil through special clays or other purifying materials, even after it has passed through a number of special refining stages. This is one reason why nearly all turbine oils are light in color—the clay decolorizes the oil in addition to finally removing possible objectionable impurities.

In the lubrication of marine turbines two contingencies must always be realized:

(a) Cessation or impairment of lubrication.
(b) Variations in the rate of heat abstraction.

The reason for the above is the fact that the

oil ways and oil piping will tend to become clogged or obstructed by sludge and emulsified matter. These latter are developed by high temperatures or the use of contaminated lubricants or products which have been improperly refined. In either case there is no logical excuse, for not only is it possible to get good turbine oils which have been carefully prepared to meet the existing known requirements, but also it is possible to sufficiently purify them while in service, in order to enable them to withstand the usual operating conditions which would tend to impair them.

To guard against any difficulties in operation, the first precaution must be to use an oil that will not emulsify readily with water. Oils which develop high organic acidity when moisture is absent will emulsify and sludge the worst when agitated in contact with moisture. There is as yet, however, no direct proof that increase in organic acidity alone, without formation of emulsions and sludges, is especially dangerous. Furthermore, attention is called to the fact that sludging is not necessarily dependent upon the presence of water, as oils will sludge from heat alone in the presence of air, but the presence of water may assist in its more rapid formation under certain conditions.

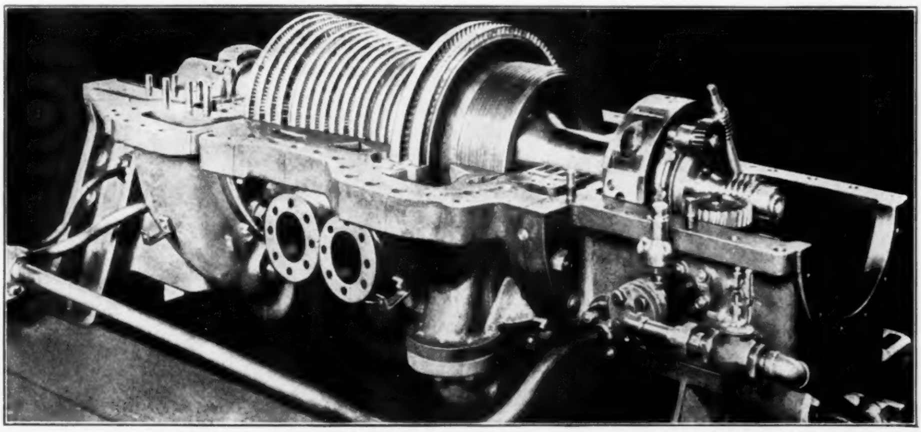
The best turbine oil is that which will most effectively withstand:

1. The oxidizing and acid-forming effects of heat and air.
2. Emulsification with water.

Oxidation

All mineral oils will tend to emulsify when subjected to oxidation and agitated with water under high temperatures in the presence of air, regardless of their refinement. Oxidation, in turn, will be accelerated by the presence of metallic particles such as brass, copper, iron, or iron rust, all of which have a catalytic influence on the reaction. These various factors are normally so involved and so contingent on one another that no one of them can be rightly claimed as being more detrimental than the other. The extent to which oxidation will occur depends largely upon the refinement of the original oil as certain petroleum hydrocarbon fractions oxidize more readily than others. Logically, therefore, it would be advisable to be most careful in their preparation to effect the removal of these compounds by accurate refining. The more reliable the manufacturer, naturally the more dependence can be placed on his methods of refining.

Yet, regardless of this, oxidation will occur even with the best of oils, if they are subjected to oxidizing conditions. Wherever particles of air are suspended or retained within the body of an oil, only a slight elevation of temperature during circulation or agitation will be necessary to bring about an oxidizing reaction. Foreign matter, such as brass, copper, iron, dust and dirt are regarded as being the co-partners of oxidation in producing the resultant insoluble sludges so detrimental to proper lubrication.



Courtesy of Allis-Chalmers Manufacturing Co.

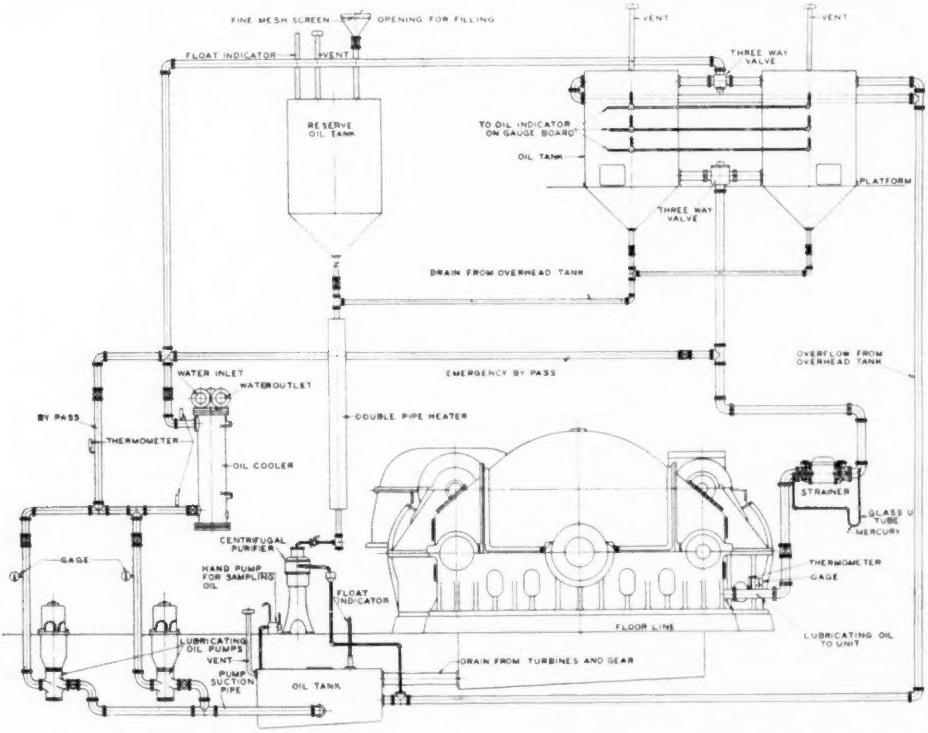
Fig. 2—Details of the blading and bearing assembles of a typical Allis-Chalmers Marine Turbine.

3. Development of sludges from such emulsification.
4. The catalyzing effects which dust, dirt and metallic particles (especially of copper and brass), involve in the formation of sludges.

It is claimed that if emulsification is prevented, sludging will be greatly reduced. As emulsions involve only oil and water, it would, therefore, seem logical to consider foreign matter, or the catalyzers which promote oxidation, as an equal detriment. Emulsions alone

are certainly not as viscous, adhesive and generally objectionable as insoluble sludges which so frequently clog oil passages, congest the oiling system and generally reduce the lubricating quality of the oil.

The natural procedure is to reduce the effect by removing the cause as far as possible. This is accomplished by purifying the oil during operation to a sufficient degree to keep down the percentage of water, emulsion and foreign matter. The latter can also be prevented to a considerable extent by using steel piping and fittings throughout the oiling system, for steel has the least tendency to chip, corrode or otherwise contaminate the oil with metallic particles.



Courtesy of De Laval Steam Turbine Company

Fig. 3—Arrangement of lubrication system (in elevation) for a De Laval Marine Steam Turbine. Note relative location of tankage drains, pumps, strainers and the centrifugal purifier.

Demulsibility

Demulsibility indicates the tendency or speed at which an oil emulsion will break or separate into its respective components—oil and water. This will depend largely upon the degree of refinement employed, the care used in fractionating or segregation of distillates, and the extent to which distillates designed for turbine service are subsequently refined.

With heavier or more viscous oils emulsified matter will settle out more slowly than from more fluid products or those of lighter body. This will be especially true where the same conditions of refinement prevail. It is one reason why a turbine oil should be of low to medium-heavy viscosity, commensurate, of course, with other conditions, such as the operating temperature of the bearings, the gallonage capacity of the lubricating system, the period of rest, and the means provided for separation of non-lubricating foreign matter.

Sludge Formation

The natural sequence to subjecting an overheated turbine oil to agitation in the presence of air or water is the formation of permanent sludge. Sludge is generally agreed upon as passing through various stages in its formation, i.e.,

1st. The colloidal sludge stage and

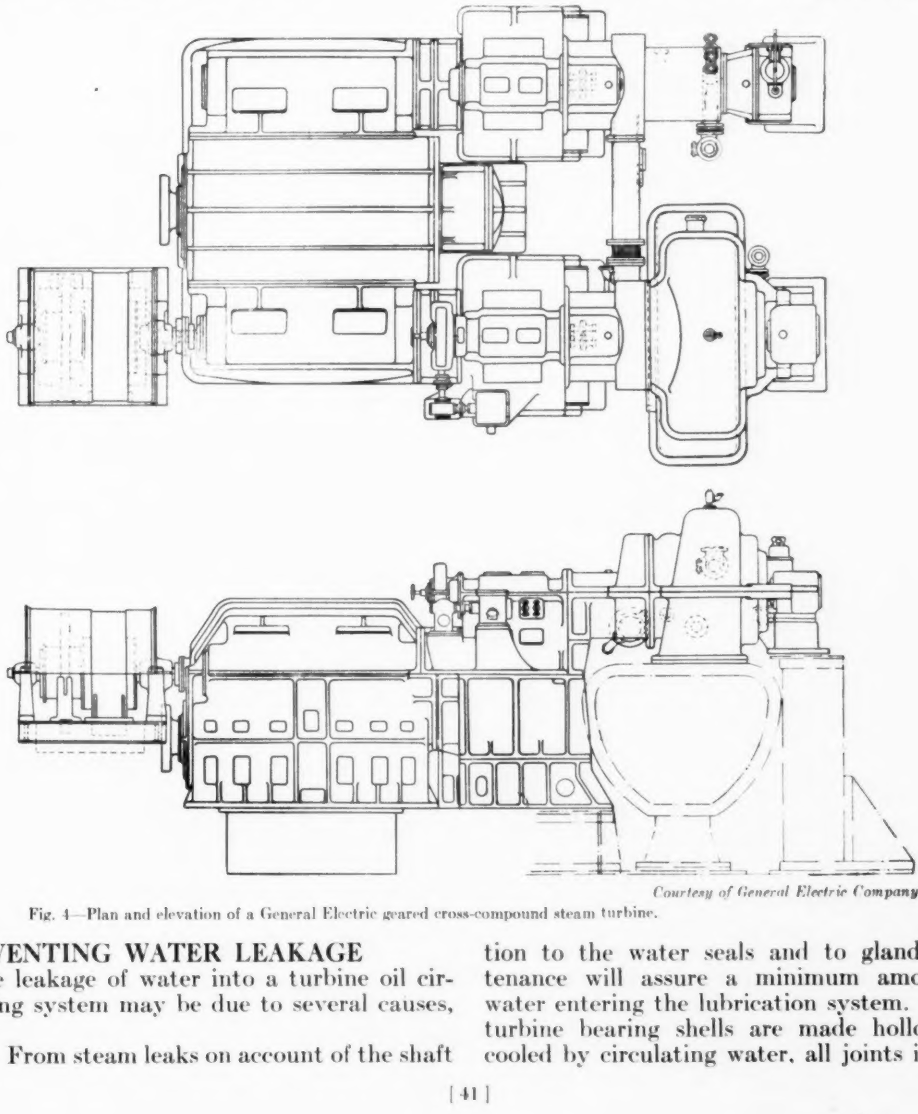
2nd. The insoluble sludge stage.

In the colloidal stage, if water is present, fairly stable emulsions may be formed. On the other hand, colloids are not necessary for the formation of emulsions. If these latter contain uncontaminated and unoxidized oil, they will clarify themselves and precipitate water on standing, leaving the bulk of the oil in very nearly the same condition as prior to agitation. Colloidal sludges in turn, form more or less

stable emulsions with water. Yet while both emulsions and colloidal sludges can be apparently readily dissipated from the oil, they are nevertheless a detriment to lubrication while present, due to the fact that the formation of a continuous, uniform oil film over the surface to be lubricated is prevented.

Furthermore, in oils where breakdown has occurred, separation of contaminating foreign matter will be retarded. As a consequence, this latter will be able to exercise its catalyzing effects to co-operate with oxidation in the bringing about of permanent sludges.

Of course, where colloidal sludges have passed over to the second stage, immediate steps should be taken to correct this by the removal of the heavy, adhesive, relatively solid matter from the system, otherwise lubrication will be bound to be impaired.



Courtesy of General Electric Company

Fig. 4—Plan and elevation of a General Electric geared cross-compound steam turbine.

PREVENTING WATER LEAKAGE

The leakage of water into a turbine oil circulating system may be due to several causes, viz.:

(a) From steam leaks on account of the shaft packing glands or water seals not functioning properly.

(b) Through leaks in the cooling coils of the oil cooler; or,

(c) As is more usually the case, from condensation of moisture in the air.

The latter will be especially likely to occur when the turbine is shut down, at which time the inner metallic surfaces of the lubricating system will be relatively cold, serving more readily as a condensation medium.

Glands

The shaft glands of turbines are sometimes fitted with carbon packing rings held against the shaft by springs, by labyrinth packing or water seals, or by water throwers introduced between packing glands. When starting and stopping a turbine installation, careful attention to the water seals and to gland maintenance will assure a minimum amount of water entering the lubrication system. Where turbine bearing shells are made hollow and cooled by circulating water, all joints in these

coils must be kept tight to prevent water entering the system from such leakage.

The construction of some turbines also provides for a combined steam and water-sealed type gland for preventing leakage where the rotor emerges from the casing. The water gland

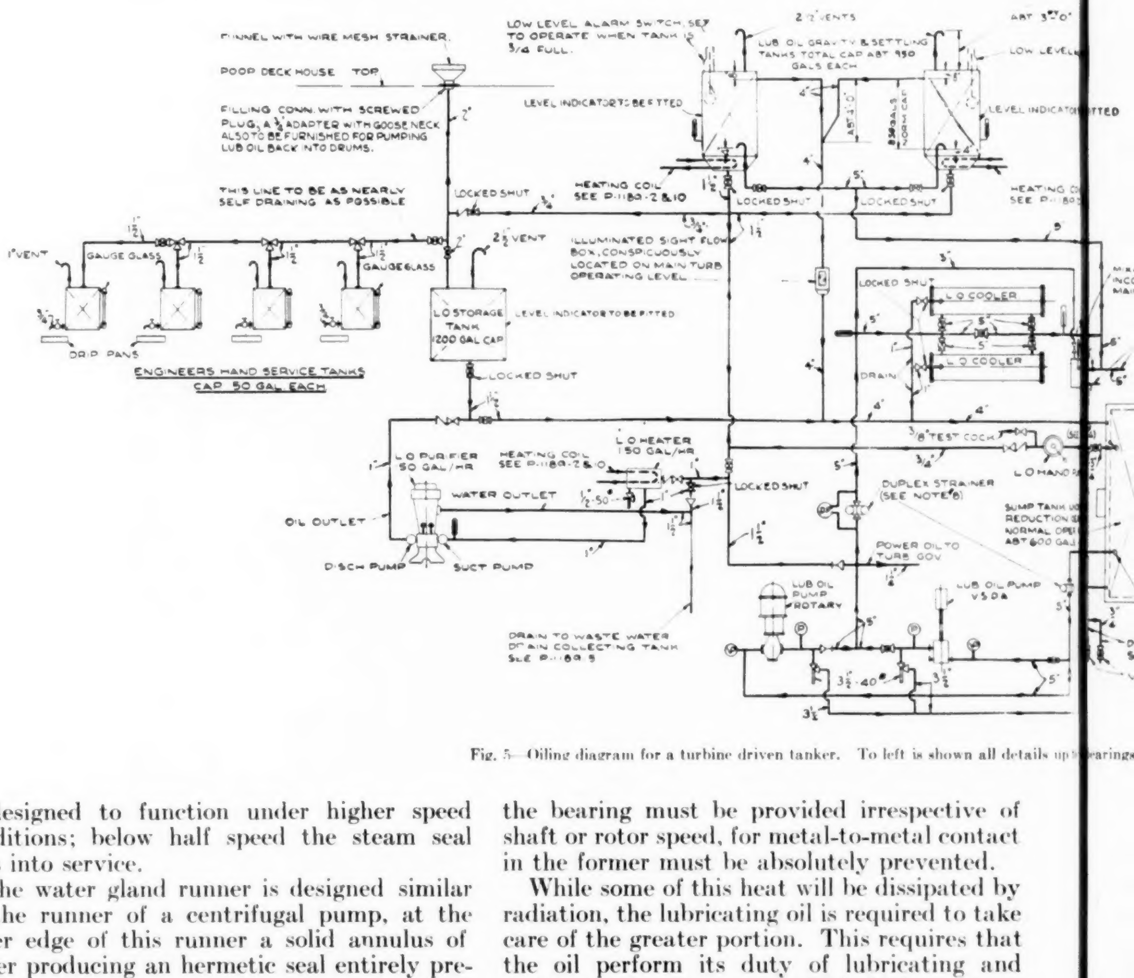


Fig. 5—Oiling diagram for a turbine driven tanker. To left is shown all details up to bearings

is designed to function under higher speed conditions; below half speed the steam seal goes into service.

The water gland runner is designed similar to the runner of a centrifugal pump, at the outer edge of this runner a solid annulus of water producing an hermetic seal entirely precluding steam leakage. Any water that may leak out of the gland on the outside is carried away by a free drain; this must be maintained clear at all times, otherwise water may accumulate, to rise high enough in the cavity between the gland and bearing to leak past the oil ring into the bearing chamber and contaminate the oiling system.

OPERATING CONDITIONS

Turbine bearings are subjected to heat from three possible sources, i.e.,

1. The heat from the steam passing through the machine which is conducted by the shaft from the interior,
2. The heat generated by internal friction in the lubricant, or,
3. Imperfections in design or adjustment which may lead to misalignment or unequal pressure on the bearings.

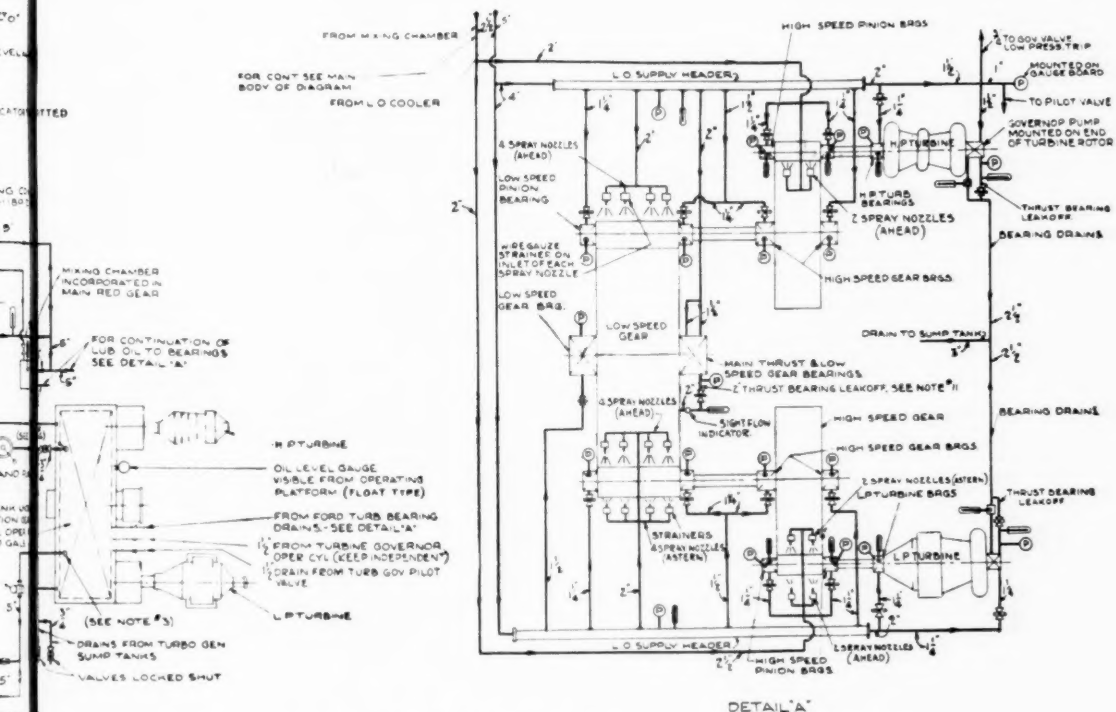
Under these conditions positive lubrication of the bearing must be provided irrespective of shaft or rotor speed, for metal-to-metal contact in the former must be absolutely prevented.

While some of this heat will be dissipated by radiation, the lubricating oil is required to take care of the greater portion. This requires that the oil perform its duty of lubricating and cooling the bearings at relatively high temperatures; in turn, it must have the ability to readily give up this heat which it has absorbed when it is passed through the cooler. The intensity of the bearing temperatures in any turbine will depend upon the design of the turbine itself and the rate at which the oil is being circulated.

Heat as received from the steam may be either conducted or radiated. At the high pressure end of the machine, conduction will be more probable, for steam at temperatures in the neighborhood of 600 degrees Fahr. or above will certainly lead to active heat transfer to the adjacent bearings, regardless of the provisions

for cooling. Transmission of heat by radiation to the bearings as well as to the oil piping will also occur to a certain extent, although this will depend upon the provisions for ventilation, and the operating temperature of the turbine room.

Since one of the functions of the turbine oil



Courtesy of Bethlehem Steel Company

...earings; detail "A" shows these latter with their necessary oiling appurtenances

is to serve as a bearing coolant, it is obvious that every precaution must be taken to keep the lubricant under circulation within a controlled temperature range. It is especially important to watch the cooling range; normally 100 degrees Fahr., can be taken as a safe minimum.

Most positive protection can be attained by flooding the bearings with an excess of the right grade of oil under controlled pressure. An adequate supply of oil will, in turn, automatically control the bearing temperature. In this connection, it is important to remember that, while heat alone will lead but to the possibility of faulty lubrication from the viewpoint of lack of pressure-resisting ability, heat in company with water and air will be the forerunner of oxidation, emulsification, and the subsequent formation of insoluble sludges. Every effort should be made, therefore, to keep the turbine bearings and consequently the oil temperatures as low as possible. This is the primary reason for installing an oil cooler in connection with the lubricating system.

Bearing Temperatures

Turbine bearings can usually be run at higher temperatures than the bearings of reciprocating engines. They must, however, be carefully watched at all times, for any indication of abnormal temperature rise must be investigated immediately. In other words, one must be concerned over any increase above the usual operating temperatures.

These latter will vary, of course, dependent on climatic conditions, as well as the temperature of the sea-water which is used for cooling purposes. The ideal from a lubricating viewpoint, is to keep the bearing temperatures in the neighborhood of 140 degrees Fahr., although a fair range is from 145 degrees to 165 degrees. If the temperatures go much above 170 degrees Fahr., at any time, trouble may be impending; then the engineer should investigate the suitability of the oil or the extent to which foreign matter and sludge may be present.

Where the bearings may be ring-oiled, as in the case of certain types of auxiliaries, the temperatures are liable to run somewhat higher

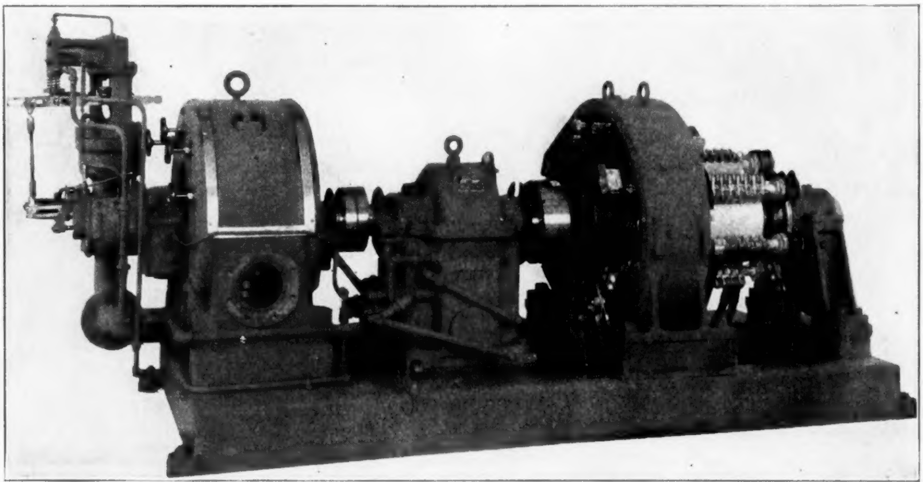
than are experienced with force-feed lubrication. Obviously, this would be expected, for the oil in a ring-oiled bearing will have far less cooling effect than in a flood-pressure system involving a considerably greater volume of oil.

Here again, therefore, we must consider the effect of temperature upon the viscosity of the oil, especially when making initial selection of the latter.

We know that all oils decrease in viscosity with increase in temperature; conversely, they become more viscous as the temperature decreases. Therefore, to attain the most efficient lubrication it is essential to consider the viscosity of the oil at the normal operating temperature. Should it be desirable to decrease the bearing temperature, a lighter bodied oil, i.e., one of lower viscosity, should be used. On the other hand, if high clearances exist or other unusual mechanical conditions prevail, a somewhat heavier oil than usual can often be used to advantage. Under conditions of this nature, the use of lighter-bodied oils might lead to trouble, because the oil would not have sufficient film thickness to keep the high points of the surfaces apart.

Atomization

As the oiling system in a well designed turbine is usually tightly enclosed, there is very little loss of oil by actual leakage, the initial charge should, therefore, last a long time. Any petroleum oil when agitated in the presence of air at elevated temperatures, however, will atomize to a certain extent, depending on the nature of its refinement. Some of the oil will consequently be driven off, no matter how tightly the system may be enclosed.



Courtesy of The Terry Steam Turbine Company

Fig. 6—Showing the Terry design for marine auxiliary service. This is a turbo-generator set rated at 150 KW. The bearings thereof are designed for a combination of ring-oiling and force feed lubrication; the gear set being full pressure lubricated.

LUBRICATING OIL SYSTEMS

Lubricating systems in marine service will differ according to the method of drive and the type of turbine used. Before the development of high ratio speed reduction mechanisms, oiling systems were considered solely from the viewpoint of lubrication; the main requisites were a product of proper viscosity to afford good lubrication, and sufficient flow of oil to dissipate the heat. There was no connection between the oiling and governing systems, and dependence was placed on alarms, gauges, etc., to warn the engineers in case of interruption of the oil supply. This latter, in turn, might be furnished by gravity, by a direct pressure system, or by a combination of both.

In the modern turbine, however, the oiling system is coupled with an emergency tripping device, which will automatically shut down the unit should the oil supply be cut off, or delivered at too low a pressure. Experience has shown that the lubricating oil system is the most vital part of a geared turbine installation. A large proportion of the troubles reported from turbine-propelled ships in the past have been traced either to lack of oil or to the use of oil that became contaminated by water or dirt. Assuming the best possible equipment and layout to have been provided, it is then of prime importance that the engineering staff exercise the utmost care to insure that the system is properly operated.

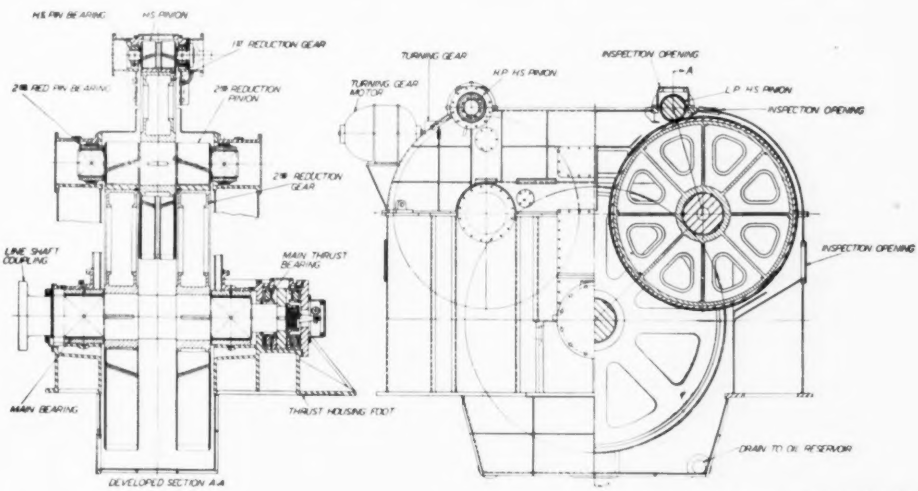
Two classes of lubricating systems are found on board modern turbine electric driven vessels —one in which the oil pump is driven by means of a worm gear from the forward end of the turbine, and the other in which separate oil pumps are provided.

Gravity Distribution

Where this system of lubrication is employed, gravity is only made use of as an adjunct to oil delivery to the turbine bearings; pumps are necessary for oil-return to the purifiers and overhead storage tanks. In other words the oil must be continually returned to one or more tanks located at the highest point available in the ship's engine room; from here it is allowed to flow by gravity to the bearings and gear sprays on the main propelling unit.

Thirty feet constitute the usual minimum height at which any gravity tank should be placed above the operating platform level. Under these conditions the lowest pressure at the bearings will range from 10 to 12 lbs. When the oil has passed through the bearings and gears and drained into the sump, it is cooled, strained and subjected to filtration or centrifugal purification after which it is pumped back to the overhead gravity tank for recirculation. Gravity oiling is preferred by many because:

1. There is a steady, uninterrupted flow of oil; whereas with the pressure system the flow may be more or less pulsating where a reciprocating pump is installed.
2. Due to the oil being returned periodically to an overhead tank, where it is allowed to rest momentarily, any air which may be contained has an opportunity to escape.



Courtesy of Westinghouse Electric & Mfg. Co.

Fig. 7—Showing a combined longitudinal and transverse section of a Westinghouse reduction gear. Note that the former is a developed section along the line A-A.

3. It is reliable due to the fact that if the oil pump stops there will still be a few minutes' supply of stand-by oil in the gravity tank to keep the bearings lubricated until the spare pump can be started or the main machinery shut down.

The success of a gravity oiling system depends largely on the pipe line from the tank to the equipment being direct, i.e., with the minimum number of bends, and of sufficient diameter to insure proper pressure on the system. The sizes of the gravity tanks in marine service vary from a minimum of about 250 gallons capacity to a maximum of 600 gallons. The total amount of oil in a system naturally varies with the size of the installation and the rate of circulation. This latter must obviously be dependent upon the design of the lubricating system, the size of the turbine, the prevailing bearing temperatures, the oil pressures, size of piping and the provision for free return of the oil. In a system circulating oil at a rate of 150 gallons per minute, if the oil is to repeat this cyle at five minute intervals, 750 gallons would be required in the system.

Direct Pressure System

Continuous circulation of oil by direct pressure likewise has its advocates and advantages. Chiefly, it is often cheaper to install than a gravity system since less equipment is required. In its operation, the lubricating oil pumps draw the oil from the sump, drain tank or purifying system through coolers, etc., as in the gravity system, and deliver it to the unit bearings under pressure. No reserve tank is provided and as the oil drains back to the sump tank it is again picked up by the pumps and the cycle repeated.

Any direct pressure system must be of ample size in order that the circulation of oil will not be too rapid. Where units are operating with too small a quantity of oil in the system the circulation of this latter may be so rapid that there is but little time for it to settle and cool.

Under such conditions not only may the bearings suffer, but also the oil may break-down more readily.

To function properly, the pressure system should always pump oil to the bearings in excess of the amount required, a relief valve or other means being provided to drain the excess oil back to the sump tank. An advantage of the direct pressure system is that it is possible for the engineer to obtain practically any desired pressure on the bearings merely by regulating the oil pump.

In some turbine installations two oil circulation systems have been used, independent of one another, one system supplying the bearings while the other takes care of the gears. While such an installation obviously requires considerably more equipment and attention, it is the ideal method theoretically as each system can be supplied with the oil best adapted for the prevailing operating conditions, viz.; the bearings being furnished with a light oil best suited to high speeds, while the gears receive a heavier oil that is most capable of meeting the pressure and temperature requirements.

LUBRICATING ACCESSORIES

The amount of apparatus necessary for an oiling system is dependent on the size and number of units employed in a marine turbine installation; likewise on the type of drive, i.e., whether it is direct, single or double reduction geared, or turbo-electric.

The operation of the gravity and direct pressure lubricating systems has already been explained. With regard to the component parts: each has a definite function which must be maintained if the turbine is to operate successfully. The general layout of the simplest type of oiling system will comprise the settling tank, the gravity drain tank, oil pump, oil cooler, oil strainer, oil purifier, and reserve oil tanks. The larger the job the greater would be the number of units required.

Settling and Gravity Tanks

Reference has already been made concerning the overhead supply tanks which are installed in conjunction with a gravity lubricating system. Not only do these tanks insure constant uniform pressure on the oiling system and serve to eliminate pulsations as transmitted from a reciprocating pump when used in a closed system, but they also offer a storage reserve in case of stoppage of the oil pump. Furthermore, they serve as settling tanks from which any sediment and water may be drawn off to a purifier. A float alarm connected up with a gong or whistle is installed to notify the engineer in case the oil supply should fall below a safe level due to any cause whatever.

Overhead tanks are installed in duplicate so that one can be held in reserve. This can be used for storing oil while cleaning the oil drain tank or its companion supply tank. Such tanks should have conical bottoms so that any sediment or water can be completely drained to the purifier. The main oil supply line is taken off above the conical bottom of the tank, thereby leaving the lower portion for collecting and disposing of sediment.

In turn, to prevent entry of water or foreign matter all such tanks should be fitted with tight covers and a vent pipe protected with a hood and a fine screen. Overhead tanks are also supplied with an overflow-line piped directly to the main drain tank so that in case of an over-supply of oil from speeding up of the oil pumps they will not overflow through the vent.

Oil Drain Tank

This tank must be placed sufficiently below the turbine to insure complete drainage of the turbine and gear casing, regardless of how the vessel may be rolling or pitching. Oil backing up in a gear case will cause excessive heating of the gears and if it becomes flooded the turbine may have to be shut down to release the oil from the upper portion of the case where it is held by the windage from the gears. The bottom of the oil tank should slope slightly in a fore and aft direction for drainage, with the suction lines to the oil pumps located some distance above the bottom. This assures that only good clean oil is drawn into the circulating system, meanwhile the lower portion of the tank is available for collecting sediment and water.

The capacity of oil drain tanks will vary according to size of the turbine; they must be sufficiently large, to allow the oil to come temporarily to rest, free itself from air and foam, and settle out impurities and water. An air vent to release air and vapor from the tank is provided, also a float indicator to show the height of the oil in the tank. Perforated baffle plates similar to those provided in the gravity tank are installed in the drain tank to prevent excessive splashing.

Oil Pumps

These elements which may be of either the reciprocating or rotary type, are installed in duplicate, each of sufficient capacity to supply the necessary quantity of oil to the turbine bearings and gears. With such pumps it is possible to place the oil cylinders below the level of the oil in the drain tank; this requires less floor space and enables proper arrangement. By eliminating the suction head the formation of air pockets is prevented; these would otherwise cause intermittent flow of oil and increased wear on the gears, thrusts and bearings.

Should the pump suction fail to be covered with oil, it may be due to the rolling of the vessel, improper location of the suction, or installation of the drain tank in one of the wings of the ship instead of along the center line. In some installations an automatic regulator is installed between the two oil pumps so that in the event of the pump which is in operation ceasing to function, the other will automatically start pumping. Bronze valves and metallic packing should be used throughout the pumps since fibre packing has a tendency to disintegrate and get into the oiling system.

The Oil Cooler

The function of the oil coolers is to keep the lubricating oil at the proper temperature and to prevent overheating of the oil in the system which might in turn cause overheating of the bearings, gears or governor mechanism. All frictional heat from the bearings and gears, as well as any heat transmitted by the steam to the bearings is taken up by the oil; this heat must be removed by the cooler.

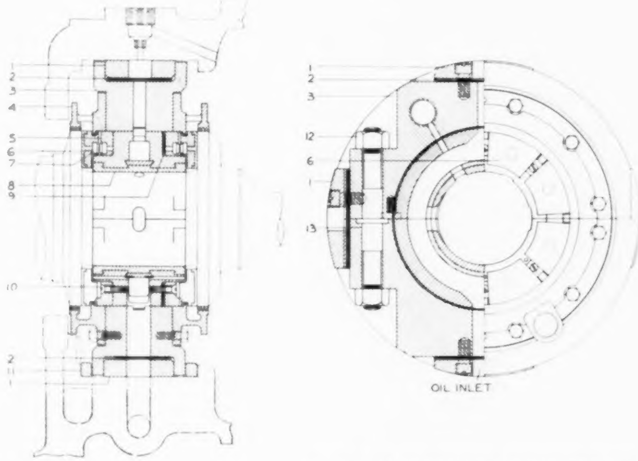
Oil coolers are also installed in duplicate, operating either in series or in parallel. One is usually held in reserve, a by-pass being provided so that one or the other can be cut out for repair or cleaning at any time. Oil coolers are always installed between the oil pump and the overhead tanks, and not between the overhead tanks and the turbine, as the friction of the oil passing through the cooler may reduce the head below that required for proper lubrication.

The importance of keeping water out of the lubricating system has already been discussed. In consequence any sign of water in the system calls for immediate examination of the oil cooler to make certain there are no leaky tubes. The oil may either pass around or through the tubes, according to the type of cooler used. The pressure on the oil side of the cooler should always be slightly in excess of that prevalent on the water side so that in the event of leakage the tendency will be for the water to be kept out of the oil side. To test for oil leaks, a drain connection is provided on the cooling water discharge line, from which a sample can be drained at any time for examination. Oil coolers must be inspected periodically as the tubes or coils may accumulate deposits from the oil on one side or from the water on the other side, thus interfering with the circulation of the oil and the rate of heat transfer.

Oil Strainers

Two types of oil strainers are in general use on board turbine ships, viz.: the duplex pressure strainer and the gravity strainer with flat vertical screens.

A duplex strainer is always placed on the pump discharge, never in the suction line. It is so arranged that one basket may be cleaned while the other is in service, and when it becomes clogged the valves are turned so that the oil passes through the clean basket. A by-pass is usually provided equipped with a spring-loaded check valve set for about five pounds pressure, so that as soon as the strainer becomes choked the increase in pressure will permit the oil to by-pass with no interruption in flow.



Courtesy of Allis-Chalmers Manufacturing Co.

Fig. 8—Section through an Allis-Chalmers journal and thrust bearing. Note the point of oil inlet at the base with the overflow at the top of the oil retainer, so that the thrust shoes will operate in a bath of oil:

1. Bearing Block
2. Shims
3. Bearing Casing
4. Oil Retainer
5. Base Ring
6. Thrust Shoe
7. Steel Button
8. Bearing
9. Shims
10. Screw
11. Lock Ring
12. Nut
13. Collar Stud

The construction of the gravity type of strainer automatically eliminates the possibility of stoppage of oil, and since the oil flows through the screens by gravity alone it must necessarily be placed at the top of the system on a level with the gravity tank. Such a strainer consists of a rectangular box in which are placed several screens, through which the oil passes in succession. Each succeeding screen is of smaller mesh than the preceding to assure the filtering out of all foreign matter.

As the oil is not forced through the screens by any pressure from the pump but merely by a difference of the oil level on the two sides of the screens, as the latter become clogged this difference becomes greater and of more assistance as a filter aid.

The Purifier

The lubricating oil purifier which may be either of the centrifugal or filter type, is usually installed directly below the overhead settling tank from which it receives its oil supply. The centrifugal purifier is very widely used in marine service. It should be operated long enough daily to take care of the dirty oil which has been drained into the settling tank. The purified oil is led back to the drain tank. It is good practice to pass all the oil in the system through the purifier at the end of each voyage.

A marine purifier should have a capacity of not less than 100 gallons per hour; and the best results will be obtained by heating the oil to about 180 degrees Fahr., before passing it through such a device.

REDUCTION GEARS

The development of reduction gears for marine propulsion service has an interesting background. Years ago when the change from paddle-wheel to screw propeller took place, engineers were chiefly concerned with the problem of securing the necessary increase in propeller revolutions. There was no satisfactory means available whereby a sufficiently high piston speed could be secured to permit the engine to be coupled directly to the propeller; accordingly, the propeller-shaft revolutions had to be increased by means of gearing. Gradually, as improvements in mechanical design were effected, piston and shaft speeds became so synchronized that gearing—usually regarded as an unsatisfactory compromise—became no longer necessary. The advent of the higher speed steam turbine, however, brought gearing again into consideration, but this time the gears performed an exactly opposite function in that they served to reduce the speed transmitted to the propeller.

Direct drive from the turbine to the propeller was of course practiced at first, when the desired speed was not too low to impair the efficiency of the turbine nor so high as to adversely affect the efficiency of the propeller. It was soon appreciated, however, that most economical operation would be gained by using some means of speed reduction to enable the turbine and propeller to operate at their most efficient and natural speeds; hence, the research into gear design.

Lubrication of Gears

When reduction gears were first applied to marine service, their lubrication was immediately noted to be quite different from that prevalent in direct-drive turbine installations. The ideal seemed to call for two complete lubricating systems—one carrying a low viscosity oil for the turbine bearings, the other a high viscosity oil for the gears. Obviously this duplication of equipment, together with additional space and cost requirements, could not be favored in marine practice, so a compromise was sought, the problem being solved by the selection of one lubricating oil which would effectively serve both turbines and gears. This is customary practice today.

Obviously, the viscosity must be given most careful study. If it is too low, the oil may not be able to withstand the prevailing tooth pressures and surface wear will follow. There is a slight slippage in the meshing action in all gears; the duty of the lubricant is to prevent or reduce to a minimum the amount of metallic contact which may result from this action. In marine service where the gears are served by the same lubricating system as the bearings, the oil must be of sufficient viscosity at the operating temperature to successfully withstand these high tooth pressures and prevent wear. It must also be completely fluid and free of air entrainment; for this reason drains from gears should always be led to the return tank above the operating oil level in order to allow the return oil to free itself of foam.

This use of the same lubricant for both gears and bearings requires a certain increase in viscosity over that required for direct-drive turbines in order to insure effective lubrication of the gears.

The oil must never be so heavy, however, as to lead to the development of abnormal internal friction within itself as it passes through the bearing clearances. An oil with a steep viscosity curve has been found to be the most adaptable for such service; such an oil will maintain its original viscosity when in service under normal temperatures in the gear case, and still it will be capable of decreasing so rapidly in viscosity with normal increases in temperature that when fed to the bearings at temperatures in the neighborhood of 140 degrees Fahr. it will be reduced to approximately the right viscosity for bearing lubrication.

No oil for reduction geared turbines should ever be of higher viscosity than absolutely necessary, because the heavier the oil the less rapidly will it separate from water. For such service a highly refined turbine oil having a viscosity of 300 to 500 seconds Saybolt Universal at 100 degrees Fahr., is generally suitable.

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